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MEMORANDUM

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Subject: Gasoline Production Capacity Impacts of Fuel Control Options

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To: The Record

EPA's charge from the NEPD included exploring ways to increase the flexibility in the distribution infrastructure, improve fungibility, and provide added gasoline market liquidity. In addition to looking at distribution system impacts, EPA analyzed how the various options could affect the overall supply of gasoline from refineries in the U.S. (i.e., gasoline production capacity). Analyzing the impact on gasoline production capacity is important because fuel options which significantly reduce capacity could offset some or possibly all of the benefits to the distribution system of reducing the number of fuel types. In the most extreme example, the fuel distribution system can be accommodated most completely by requiring either Federal reformulated gasoline (RFG) or California clean burning gasoline (CBG) nationwide. Either program would significantly simplify gasoline distribution, but would limit the volume of gasoline capable of being produced from today's refineries. The analysis presented below estimates the impact of the fuel control options on gasoline production capacity, so that these impacts can be combined with other aspects of the boutique fuel issue to provide an overall assessment of potential solutions to the "boutique fuel problem".

I.. Executive Summary

Table 1 summarizes the projected impacts of the various fuel options on domestic gasoline production capacity in comparison to a 2006 reference case that assumes the EPA Tier 2 sulfur and MSAT programs and state MTBE controls are in place. The total impact on gasoline production capacity is shown, along with a breakdown of this impact into three components: ethanol, MTBE and all other sources, which is primarily hydrocarbons derived directly from petroleum or natural gas liquids. As this analysis takes into account only first order impacts and is not based on a thorough study of refining technology and economics, variations of a few tenths of a percent should not be viewed as significant, but only indicative on the likely direction that any changes would take. We have not shown any of the cases involving a 0.95 volume percent benzene limit, as we project that this limit would have very little impact on gasoline production capacity.

Table 1: Estimated Impact of Fuel Options on Gasoline Production Capacity Relative to the 2006 Reference Case and Relative to the Basecase

Option	RFG Oxygen Mandate	2.4% Renewable Requirement	% Volume Change in U.S. Gasoline Pool (Positive number indicates increase)			
			Ethanol	MTBE**	Hydro-carbons	Total
Reference Case (Relative to Base)	Yes	No	0 (0.6)	0 (-1.7)	0 (1.2)	0 (0.1)
3-Fuel	Yes	No	0.1	0	0	0
	No	Yes	0.3	-0.7	0.7	0.3
2-Fuel	Yes	No	0.4	0.4	-0.4	0.4
	No	Yes	0.3	-0.6	0.6	0.3
Federal CBG	No	Yes	0.3	-0.6	-3.1 to -5.6	-3.5 to -6.0
California CBG	No	Yes	0.3	-0.6	-10.1 to -12.6	-10.5 to -12.9

The remainder of this memorandum presents the methodology used to derive these projections.

II. Overview of Methodology

Gasoline quality specifications will change between now and 2006 and the various fuel control options being considered in the boutique fuels report would change them even further. Gasoline quality specifications can affect the amount of gasoline which can be produced from a given refinery configuration. Often, these impacts can be mitigated or eliminated through relatively small investments in new or revamped equipment. In other cases, more significant investments would be needed. In estimating the impact of fuel controls on capacity, we have assumed that refiners would make the relatively small investment to maintain production capacity. Refiners have made billions of dollars worth of investment in gasoline production capacity over the past decade despite low margins. This investment has primarily been in revamps and debottlenecking of existing equipment. The higher gasoline refining margins occurring during the past two years should only accelerate this investment. Significant investments to increase gasoline production capacity are possible, but not guaranteed. Therefore, in order to more realistically project the impact of fuel controls on gasoline production capacity, we have not considered what we consider to be signficant investments in "new" production capacity not related to the full utilization of existing equipment.

We have broken down the aspects of gasoline quality which affect productoin capacity into four main areas. These areas interact, so some repetition occurs. However, we believe that breaking the impacts down in this way facilitates understanding the key factors involved and their estimation absent detailed refinery modeling.

The four areas which we have identified are:

1) limits on MTBE use and the production of other blending components from MTBE plants no longer producing MTBE,

2) RVP limits,

3) changes in ethanol use, and

4) benzene content and toxics emission limits.

The impacts of these five factors on national gasoline production capacity are discussed below. Then, following these discussions, the overall gasoline production capacity impacts of the various fuel control options are estimated.

III. Limits on MTBE Use and Conversion of MTBE Plants

The primary factor affecting MTBE use in the future are bans on its use due to groundwater contamination concerns. As discussed in the main body of the report, several states have banned or otherwise limited the use of MTBE in gasoline sold in their state, effective in the next few years. All of these MTBE limits will be fully effective by 2006, the timeframe for this gasoline production capacity analysis.

When MTBE use is banned or limited, there are three main impacts on gasoline production capacity. First, MTBE use in those states with the limits decreases to the level of the limits or below. Second, this MTBE may be shifted to states not limiting its use. Third, idled MTBE plants may be converted to the production of other gasoline components, or the feedstocks which were used to produce may be used by refineries to produce gasoline blending components.

A. Reduction in MTBE Use in States Limiting Its Use

The impact of state MTBE limits varies by region of the country. The states which have already implemented limits on MTBE use and those which are considering such bans are described in EPA's boutique fuels report.

Practically speaking, the MTBE bans in the Midwest (e.g., Illinois, Minnesota, South Dakota, etc.) have little impact, since very little MTBE has been used in these states over the past few years. However, the St. Louis and Kentucky RFG markets have been gradually moving from being dominated by MTBE use to a mixture of MTBE and ethanol and we assume a mixture of half ethanol and half MTBE in the reference case.

The northeast states banning MTBE (e.g., New York, Connecticut) will have a much more significant impact on MTBE use, since much RFG is sold in these states and MTBE is used in nearly all this RFG. It is possible that RFG with MTBE could be sold in the other northeast states, while RFG with ethanol is sold in New York and Connecticut. This would require the distribution of two distinct RFGs in this region, plus southern RFG in Baltimore and Washington, D.C. Because of the uncertainty that this would occur, we decided to make a more worse case assumption that the MTBE bans in New York and Connecticut would eliminate MTBE from all northern grade RFG in the Northeast.

The MTBE bans in California and Arizona will eliminate MTBE from these two states, as well as adjoining states (e.g., Nevada). Washington state has also banned MTBE, though little MTBE is currently used there. Taken together, these three state MTBE bans are projected to eliminate MTBE use west of the continental divide.

Finally, no states in the southeast or south have banned MTBE. Texas has limited MTBE use to historic levels. This Texas limit would primarily affect MTBE use under scenarios where the RFG fraction of Texas fuel increases or where MTBE is banned elsewhere and an economic incentive would exist for additional MTBE use in conventional gasoline outside of the banned areas. In these cases, the new RFG could not contain MTBE, nor could its use in conventional gasoline increase in Texas. Otherwise, we project that MTBE will continue to be the dominant oxygenate used in southern grade RFG outside of St. Louis and Arizona.

With the RFG oxygen mandate still in place, the net effect of the state MTBE limits is the elimination of MTBE use from all northern grade RFG, plus southern grade RFG used in St. Louis and Arizona. Likewise, all MTBE use in California is eliminated. MTBE which is currently used in conventional gasoline would also be lost in these states. Based on EIA gasoline consumption data, this amounts to a reduction of 94,000 bbl/day of MTBE use in the Northeast and 65,000 bbl/day in California.

B. Increased MTBE Use in Conventional Gasoline

The majority of MTBE production is used in producing RFG and California CBG. However, some MTBE is currently used to produce premium and midgrade conventional gasoline. The 2000 AAM gasoline survey indicates that when MTBE is used in premium conventional gasoline, it tends to be used at the 10 volume percent level. The state MTBE bans would decrease MTBE use in the U.S. dramatically. This would both tend to reduce the price of MTBE dramatically and increase the value of incremental octane. Thus, we believe that it is reasonable to assume that refiners would use MTBE to satisfy octane needs in premium gasoline in areas where MTBE has been used in the past. Also, a significant portion of midgrade gasoline is produced by blending regular and premium grades. Thus, MTBE would also be used in these areas in midgrade gasoline at roughly half its content in premium, or 5 volume percent. Adding

MTBE to all midgrade and premium gasoline in states without an MTBE limit increases MTBE use in conventional gasoline from 21,000 bbl/day to 59,000 bbl/day, for a net gain of 38,000 bbl/day of MTBE use in conventional gasoline.

C. Conversion of MTBE Plants

Table 2 shows the sources of the MTBE used in U.S. gasoline and estimated 2000 production volumes (from Pace Consultants[1]). The total MTBE volume of 263,000 bbl/day represents approximately 3.3% of U.S. gasoline consumption. However, since MTBE contains only about 80% of the energy density of gasoline, it leads to somewhat lower fuel economy. Consequently, on a energy equivalent basis this MTBE volume represents approximately 2.7% of total U.S. gasoline consumption. More recent figures from EIA project total MTBE volume and domestic production to both be slightly lower for 2001. Since the differences are small and 2001 data is not yet complete, however, this analysis will continue to use the year 2000 data.

Table 2: Sources of MTBE Used in U.S. Gasoline Circa 2000

Type of MTBE Plant	Current Production Volume (barrels/day (bbl/day))	
	Physical Volume	Gasoline Equivalent Volume
Captive refinery plants	79,000	64,000
Propylene Oxide based merchant plants	45,000	36,000
Ethylene based merchant plants	21,000	17,000
Natural gas liquids (NGL) based plants	67,000	54,000
Imports (NGL based)	51,000	41,000
Total	263,000	212,000

If an MTBE plant converts to alkylate production, it produces 80% more gasoline in terms of energy content than it did when producing MTBE. The gain in energy comes from the fact that isobutane is combined with this isobutylene in the production of alkylate, versus the addition of methanol in the production of MTBE. Isobutane contains more energy than methanol, so the product does as well.

If an MTBE plant converts to iso-octane production, it produces 15% less gasoline in terms of energy content than it did when producing MTBE. Again, this assumes that the alkylate plant would process the same amount of isobutylene as before. The loss in energy comes from the fact that isobutylene is reacted with itself to form iso-octane (i.e., no other feedstock is combined with the isobutylene in the reaction). Thus, the energy content of methanol is lost relative to MTBE production.

Alkylate and iso-octane both have relatively high octane (90-100), though it is lower than MTBE's octane of 105. Alkylate and iso-octane have low RVP (2-6 psi). Iso-octane RVP is particularly low and alkylate RVP can be very low, though it tends to vary depending on operating condition and feedstock quality. These RVPs are lower than MTBE's RVP of roughly 8 psi. The substitution of alkylate or iso-octane for MTBE makes it easier to add ethanol to RFG and still meet the Phase 2 RFG VOC performance standards. Ethanol tends to add 1-1.2 RVP when added to RFG, so the production of a blendstock with an RVP in the range of 5.5 is needed to facilitate ethanol use in RFG. Both alkylate and iso-octane would do this. Aklylate and iso-octane also contain no aromatics, nor benzene. Thus, they facilitate compliance with the EPA Mobile Source Air Toxics (MSAT) standards which were recently promulgated for both RFG and conventional gasoline.

We will now discuss the possible fates of the various types of MTBE plants operating in the U.S., as well as those plants producing MTBE for import into the U.S.

1. Captive Refinery MTBE Plants

Pace projects that captive refinery plants would redirect the isobutylene currently used to produce MTBE to their alkylation unit if this unit has sufficient capacity or can be cost effectively revamped to a higher capacity. Isobutylene was always converted to alkylate prior to MTBE production and this would be the preferred route now, due to the higher volume of gasoline produced with alkylate versus iso-octane. However, if a refiner's current alkylation unit does not have excess capacity and could not be inexpensively increased, Pace concluded that the MTBE unit would likely be converted to iso-octane. Thus, as a lower limit for our analysis, we have presumed that all these units produce iso-octane, and as an upper limit all these units will produce alkylate. In no case will the MTBE production from these plants be completely lost as the isobutylene is available at no cost and has no other high value market.

2. Propylene Oxide Based MTBE Plants

Pace projects that propylene oxide based MTBE plants would likely to convert to iso-octane production, due to the lower capital cost involved. Pace estimates that the cost to convert a 15,000 bbl/day MTBE plant to iso-octane would cost $30 million, while conversion to alkylate would cost $60 million. Like captive, refinery plants, these plants are unlikely to shut down, since the feedstock used to produce MTBE (tertiary butyl alcohol) is produced as a by-product from propylene oxide production and has no other high value use. These plants are also very large and have the economies of scale to support conversion to iso-octane or alkylate.

3. Ethylene Based MTBE Plants

Pace projects that ethylene based MTBE plants would likely shutdown and send their isobutylene to refineries for conversion to alkylate. Thus, while the MTBE plant itself is shut down, the isobutylene volume used to produce MTBE today would not be lost. The main reason for the difference in fate for these plants and the propylene oxide based plants is their size. The ethylene based plants tend to be smaller and tend to be co-located with refineries. As a lower limit, we projected that the isobutylene used in these ethylene based plants would be used to produce iso-octane in refineries, as was the case for the captive refinery plants. As an upper limit, we used Pace's projection that alkylate would be produced.

4. Natural Gas Liquid Based Plants

Pace projected that merchant, natural gas liquids (NGL) based MTBE plants would face the greatest challenge to stay in business. These plants produce the isobutylene they need to produce MTBE from mixed, field butanes. Isobutane is first removed from the mixed butanes. Then the remaining normal butane is converted to isobutane and combined with the original isobutane. This isobutane is then dehydrogenated to form isobutylene. Producing isobutylene in this way is more costly than using isobutylene already present within a refinery or raffinate stream in an ethylene plant. It is also more costly than producing isobutylene from teriary butyl alcohol. The original mixed field butanes can be stored until winter and then blended into gasoline. Thus, sufficient revenue must be obtained from the alkylate or iso-octane production to cover the capital cost of the plant conversion plus the cost of producing the isobutylene from mixed field butanes.

Pace projects that, if these plants were to convert, they would be more likely to convert to alkylate than iso-octane production. Pace evaluated the historical alkylate price premiums over premium gasoline to assess the types of revenues that these plants could expect. During most of the past decade, these premiums would not support conversion to alkylate production. However, for part of last year and most of this year, alkylate price premiums have been consistently higher, and could be high enough to support conversion. Furthermore, under a partial or complete MTBE ban, demand for clean high-octane blending components should increase and alkylate price premiums should increase accordingly. This was in fact the case in all refining studies of California under their MTBE ban which showed significant flows of alkylate or iso-octane from the Gulf Coast to California. Plus, MTBE has consistently commanded a significant price premium over its octane blending value throughout the period of the RFG program. This was clearly due to the RFG oxygen mandate. The MSAT standards place a high value on the use of aromatic free octane. With reduced MTBE use, alkylate, iso-octane and ethanol are the best sources of non-aromatic octane available. Therefore, demand for all three of these components are likely to rise, leading to increased prices.

Consequently, under a nationwide MTBE ban, due to the uncertainty in future alkylate premiums, we have projected in the worst case that all of these plants would shut down or in the best case that all would convert to alklylate production.

5. Overseas MTBE Plants

Finally, Pace projects that most foreign natural gas based MTBE plants are likely to convert to iso-octane production, given their low feedstock costs. This is already occurring with an MTBE plant located in Alberta, Canada.

6. Combined Impact

Table 3 summarizes the results of this analysis. As can be seen, the net impact ranges from a loss of approximately 84,000 bbl/day to a gain of approximately 91,000 bbl/day, or roughly a gain or loss of approximately 1% of total nationwide gasoline volume on an energy equivalent basis.

Table 3: Gasoline Equivalent Volume with a Nationwide MTBE Ban

	Current Production Volume (bbl/day)	Lower Limit of Replaced Volume (bbl/day)	Upper Limit of Replaced Volume (bbl/day)
Captive refinery plants	64,000	54,000	114,000
Propylene Oxide based merchant plants	36,000	31,000	31,000
Ethylene based merchant plants	17,000	14,000	30,000
Merchant (NGL) plants	54,000	0	98,000
Imports (natural gas based)	41,000	30,000	30,000
Total	212,000	128,000	303,000
Change from Current		(84,000)	91,000

7. Impact Under State MTBE Bans

The previous described analysis was performed primarily in the context of a total ban on

MTBE use in the U.S. Under the existing state MTBE bans, roughly 50% of the current level of MTBE use would continue. Thus, some MTBE plants would continue to operate, while others would cease MTBE production. We believe that the MTBE plants facing the lowest conversion costs would convert to iso-octane or alkylate per the above analysis, while the highest cost MTBE producers would continue MTBE production. The lowest cost MTBE producers are likely the captive refinery plants, the ethylene based plants and the propylene oxide plants. These plants are projected to convert to iso-octane production or a mix of iso-octane and alkylate production. To be conservative here, we are simply projecting that they would convert to iso-octane production, with the accompanying 15% loss in gasoline equivalent volume. However, it is possible that a net gain would actually occur, due to refiners utilizing excess alkylation capacity or revamping these units to a higher capacity.

IV. RVP Limits

Reducing RVP to meet the VOC requirement for RFG for only a portion of the gasoline pool (as occurs under the 3-fuel and 2-fuel options) was determined to be feasible by removing only butane from the gasoline pool. This finding assumes that refiners have the flexibility to blend back and forth between the reformulated pool and the conventional pool. Thus, if refiners must remove some pentanes from their RFG pool after removing virtually all the butanes, they would shift the pentanes to their conventional pool and remove just a little more butane from the conventional pool. If a refiner is volatility constrained and is unable to shift pentanes to his conventional gasoline pool, we assume that they would sell this pentane to other refiners that are not so constrained, resulting in only butanes being removed from the overall gasoline pool. Given the much larger volume of pentane which must be removed per 1.0 psi RVP reduction versus butane, the economic incentive to find a place for pentanes in gasoline is great. Given that refiners have some flexibility in the amount of RFG and conventional gasoline which they produce, we believe that these assumptions are reasonable.

For options which require nationwide Federal or California CBG, no summertime conventional pool is available for blending in pentanes. Thus, we assumed that refiners would have to start removing pentanes from the overall summer gasoline supply. The RVP level at which this occurs is estimated to range from 6.8 - 7.5 RVP. This difference in the point at which pentane must be removed is the reason why we have projected a range of potential impacts for these two options. It is important to note that pentanes removed during the summer can be blended into winter gasoline. However, since this analysis is mainly concerned with summertime supply when demand is greatest we did not consider any blendstock shifting from summer to winter.

Accordingly, we first calculated the changes in pool RVP due to changes in the amount of fuel meeting various RVP limits (e.g., the shift of 7.2 and 7.8 RVP fuel to RFG). We then calculated the changes in pool RVP due to changes in use of MTBE and ethanol (the latter was relevant only if the change occurred outside of areas granting ethanol blends an RVP waiver). Finally, we then determined the amount of butane which had to be removed allowing a in ares and MTBE, and if the change occurs in an area where the gasoline was RVP controlled, the change in RVP was calculated and the amount of butane which would needed to be adjusted to account for the RVP effect was included in our supply analysis. For these calculations, ethanol blended in gasoline at 5.7 percent was presumed to have a blending RVP of 25 psi, while ethanol blended in gasoline at 10 percent was presumed to have a blending RVP of 18 psi. MTBE was presumed to have a blending RVP of 8 psi.

The in-use RVP levels of the various gasolines being evaluated is summarized in the following table. The in-use RVP levels are derived by evaluating survey data from the Association of Automobile Manufactures for gasoline which meets the applicable environmental fuel program.

Table 4: Actual RVP Levels Associated with Various RVP Standards

Nominal RVP Level	***9.0 RVP Limit***	***9.0 with splash blended EtOH***	***8.0 RVP Limit***	***7.8 RVP Limit***	***7.2 RVP Limit***	***7.0 RVP Limit***	***RFG***
Assumed Actual RVP Level	8.8	9.8	7.8	7.6	7.15	6.85	6.85

To reduce RVP, we estimated that butane would have to be reduced by 1.5 volume percent, and pentanes would have to be reduced by 7.5 volume percent to reduce the RVP by one pound per square inch, the measurement for RVP. We derived this reduction using information from the input tables from the refinery models of Mathpro, the Oak Ridge National Laboratory (ORNL) and another refinery industry consultant's refinery model. From each refinery model we obtained the blending RVP values for each blendstock used in a typical refinery. These RVP values are summarized in the following table.

Table 5: Estimated Gasoline Component Vapor Pressures

Component	MathPro	ORNL	Consultant X
Isobutanes	71	71	71
Normal Butane	65	65	65
C5s & Isomerate	13.3	13.3	13.8
Straight Run Naphtha	—	—	8.8
(C5-160 F)	13	12	---
(160-250 F)	2.5	3	---
Alkylate	3.5	6.5	4.9
Hydrocrackate	12.5	14	7.2
Full Range FCC Naphtha	3.7	6.9	7.1
Light Reformate	7.5	6.9	6.4
Heavy Reformate	3.8	3.9	3.3
MTBE	8	8	8

We then applied these blending RVP values to a typical gasoline blend found in a Mathpro refinery modelling study.[2] The gasoline composition is summarized in the following table.

Table 6: Baseline 9 RVP Gasoline Composition

Gasoline Blendstocks	% Volume
Isobutanes	1.3
Normal Butane	4.1
C5s & Isom	5.8
Naphtha C5-160	3.5
Naphtha 160-250	3.7
Alkylate	12.1
Hydrocrackate	4.0
Full Range FCC Naphtha	38.1
Light Reform	5.3
Heavy Reform	21.6
MTBE	0.5
Total	100.0
RVP psi	8.5

For each of the blendstock RVPs, a reduction in single RVP number consistent with converting a low RVP gasoline to RFG was modeled manually and the change in butane volume was noted. The analysis based on the Mathpro, ORNL and the other refinery industry's consultant's blendstocks showed that butane volume changed by 1.5, 1.6 and 1.6 percent for each single change in RVP. This analysis was conducted only with the reduction of normal butane, but it is likely that refiners would remove some isobutane as well. Since isobutane has a higher RVP than normal butane, we used a 1.5 percent reduction in normal and isobutane for a single number reduction in RVP. We completed a similar analysis for pentanes and we estimate that 7.5 percent of the gasoline pool would have to be removed or shifted over to another part of the pool to realize a 1 psi change in RVP.

The same type of analysis was used to estimate the RVP at which no more butanes in the gasoline can be removed to reduce RVP and thus pentanes must then be removed to lower RVP further. This analysis applies to nationwide volatility control programs, such as nationwide RFG, since there is no higher RVP gasoline into which removed pentanes could be shifted to preserve the volume of gasoline.

Before beginning this analysis, it is important to understand the amount of butanes which would remain entrained in the gasoline pool thus causing refiners to remove pentanes to further reduce RVP. Butanes remain entrained in the gasoline pool because distillation of hydrocarbons does not allow a perfect cut between the various hydrocarbons which comprise gasoline and some butanes would be expected to remain in refined streams after distillation to remove them. It is also important to know how the various refinery modelers set up the input tables of their refinery models to account for this. Mathpro said that their gasoline blendstocks do not incorporate entrained butane and that they put a lower limit on the amount of butane which can be removed from the gasoline pool. We assumed a lower limit of 1.5 percent butanes in the gasoline blend when using their gasoline blendstocks to evaluate this issue. Ensys, which has provided many of the technical inputs to the Oak Ridge National Laboratory (ORNL) refinery model, stated that the gasoline blendstocks in the ORNL refinery model were based on actual refinery streams, but did not know how much butane which was in those streams. Since the blendstock qualities were based on actual refinery blendstocks, we presumed that the blendstocks did contain entrained butane. The refinery industry consultant felt that their gasoline blendstocks contained entrained butane and that they model removing all the butane in their low RVP refining studies and we did the same.

Our analysis here showed that applying the Mathpro blendstocks to the typical gasoline blend and limiting butane reduction to 1.5 percent yielded a lower RVP limit of lowering butane to 6.2 RVP. Applying the ORNL blendstocks to the typical gasoline blend and removing all the butane yielded a lower RVP limit for lowering butane to 7.1 RVP. Applying the other refinery industry consultant's blendstock qualities to the typical gasoline blend and removing all the butane yielded a lower RVP limit for lowering butane to 6.5 RVP. Averaging these three values yields 6.6 RVP as the lower limit for removing butane before pentanes would need to be removed.

We also discussed this lower limit for removing butane with several refiners during our discussions with them about the boutique fuel issue. The refiners we spoke to reported that the minimum RVP obtainable by removing butane was from 6.8 RVP to 7.5 RVP. It is important to note that this range could represent differences in the feedstocks such as crude oil processed by different refineries, or it could represent the different refinery units which could affect the gasoline vapor pressure at which the butane is removed. It is quite possible that this difference is due to whether the refinery has a butane-pentane splitter. This splitter allows a refiner to remove nearly all of the butane from various blendstock streams using existing fractionators, not having to be concerned with the amount of pentanes that comes with the butane. Then these butane-pentane streams are combined and sent to this splitter, which recovers the pentanes for reentry into the gasoline pool. Whatever the cause, we decided to represent the vapor pressure breakpoint at which butane can no longer be removed to reduce RVP as a range. We chose 7.5 RVP as the upper part of this range, and 6.8 RVP as the lower part of this range.

V. Changes in Ethanol Use

We have assumed that ethanol is the primary oxygenate which replaces MTBE when MTBE is banned and the RFG oxygen mandate remains. There is also the possibility that other oxygenates could be used as well. Other ethers which could play an important role in meeting the RFG oxygen requirement include ethyl tertiary butyl ether (ETBE) and tertiary amyl methyl ether (TAME). However, refiners have expressed concern over the use of these other ethers because they act in a very similar fashion in the groundwater as MTBE when released into the environment. For this reason, we believe that once MTBE is banned in an area, that the only realistic option for its replacement is ethanol. Further supporting this presumption is that some states have also banned or in some way limited the use of these and other ethers.

As a replacement for MTBE for meeting the RFG oxygen standard, ethanol only needs to be blended into gasoline at 5.7 percent compared to MTBE's 10 - 11 percent. This difference is permitted because ethanol is about 35 percent by weight oxygen versus the 18 percent by weight oxygen for MTBE. Interestingly, the increase in vapor pressure caused by blending ethanol into RFG is about the same for 5.7 percent and 10 percent ethanol blends. By itself, this factor alone might cause the refining industry to want to blend ethanol at the higher blend of 10 percent. However, at the higher volumes required under the MTBE bans, ethanol is expected to demand a significantly higher price, mainly because the likely feedstock in the short and medium term, which is corn, increases in price as demand increases and the value of the associated by-products decreases. In a refinery modeling study done for EPA by Pace Consultants Inc. on the cost of banning MTBE, ethanol replaced MTBE as the oxygenate to meet the RFG oxygenate requirement at rate of use of 5.7 percent. We assumed this rate of ethanol use in RFG in this analysis as well. Thus, to replace MTBE, 87,000 barrels per day ethanol is used in California RFG and in Northern RFG, but ethanol use in Chicago, Milwaukee, St. Louis and Louisville decreases by 14,000 barrels per day as the use there decreases from 10 percent to 5.7 percent.

Under the renewable fuel mandate, we also assume that ethanol is the only qualifying gasoline blendstock.

There is also the issue of ethanol use in conventional gasoline in the face of increasing demand in RFG. First, ethanol is normally splash-blended into conventional gasoline at 10 percent. In the reference case, because of the increase ethanol price associated with its increased use, we project that there would be a 50 percent decrease in the use of ethanol in the conventional pool. We based this projection on an analysis of current ethanol use in conventional gasoline and the level of each state's ethanol subsidy. Essentially half of all current ethanol use in conventional gasoline occurs in states without a significant ethanol subsidy (i.e., less than 10 cents per gallon of ethanol). Since ethanol is currently used in states with less than a 10 cent per gallon ethanol subsidy, we believe that it is reasonable to project that ethanol would still be used in states with a subsidy greater than 10 cents per gallon, since we do not project that ethanol's price increase would be much greater than 15 cents per gallon. However, such a price increase could cause fuel suppliers to cease blending ethanol into conventional gasoline absent significant state subsidies. Therefore, ethanol use in the conventional gasoline pool was projected to decrease by 15,000 barrels per day because of this change in use.

For cases that involving the renewable fuel requirement, ethanol use was assumed to be equal to the mandate. This was equivalent to ethanol use of 170,000 barrels per day, which is roughly 70,000 bbl/day more than current levels.

VI. Benzene Content and MSAT Standards

One of the fuel control options evaluated in the EPA boutique fuel study is a 0.95% standard for the benzene content of conventional gasoline. EPA conducted a detailed review of benzene reduction techniques in its recent MSAT rulemaking. These techniques focus on reducing the benzene content of reformate while maintaining octane. Some techniques involve removing the benzene precursors prior to their being converted to benzene in the reformer, while others involve removing benzene from the reformate after the benzene is formed. There are pros and cons involved with all of the techniques and it is likely that different refiners would choose different techniques.

Benzene is currently only 1.1% of conventional gasoline, so a 0.95% average standard would not involve a lot of gasoline material. Of all of the techniques, that producing the greatest reduction in gasoline volume would be extraction, since either benzene or benzene and higher aromatics are removed from the gasoline pool and sent to the petrochemical market. However, we expect few refiners to add extraction equipment if they are not already doing so, do its high capital cost and the need to be located near a petrochemical market (e.g., the Gulf Coast). The remaining techniques involve essentially no loss in gasoline volume and some actually increase volume. Thus, overall, we project that a 0.95% benzene standard would not affect gasoline production capacity significantly.

The recently promulgated MSAT standards were designed to prevent backsliding of toxics emission control in the future. Absent changes in refining operations, they should impose little cost or impact on gasoline production. However, the state MTBE bans would remove a significant source of gasoline volume and octane which helps reduce toxics emissions relative to other gasoline blendstocks. The EPA Tier 2 gasoline sulfur standards will mitigate some of this loss. Reducing sulfur reduces toxics emissions. Also, many desulfurization technologies reduce olefin content, which also reduces toxics emissions. We believe that it is reasonable to project that gasoline olefin content will decrease by roughly 50% on average with compliance with the Tier 2 sulfur standards. However, lower sulfur and olefin contents do not fully compensate for removing MTBE, even if aromatics and benzene levels are held constant. Adding ethanol at 5.7 volume percent or higher, however, as is required under the oxygen mandate, fully compensates for removing MTBE. Thus, the combination of lower sulfur and olefin contents, ethanol at 5.7 volume percent and iso-octane from idled MTBE plants appears to at least compensate for the removal of MTBE. Thus, for those cases with the RFG oxygen mandate, we do not project that the MSAT standards should affect gasoline production capacity. One caveat is that this analysis applies to the average refinery. The MSAT standards are refinery specific and some refiners have to meet a more stringent toxics standard than others. The effects of the individual fuel quality changes mentioned above might not be sufficient for each and every refinery. One option for such refiners would be to use more ethanol or iso-octane, since both should be available on the open market and can be used more or less by individual refiners according to their economics.

Analyzing the cases without the RFG oxygen mandate is more complex, due to the greatest variety of options available to refiners. Of course, refiners could choose to blend 5.7

volume percent ethanol into their RFG and avoid any impact on gasoline production capacity. Even without the RFG oxygen mandate, Mathpro projected that 50-65% of all gasoline in California would contain 5.7-7.8 volume percent ethanol under that state's MTBE ban. Thus, some ethanol is likely to be used in RFG/CBG on both the East and West Coasts to meet gasoline volume, octane and emission specifications. In California, alkylate and iso-octane imported from the Gulf Coast supplanted ethanol use relative to that under the RFG oxygen mandate. The same would likely be true in the Northeast. The renewable fuel mandate increase ethanol volume more than under the RFG oxygen mandate. Thus, even more non-aromatic octane and volume is available. Even if more ethanol remains in the Midwest than under the RFG oxygen mandate, this should free up alkylate in the Gulf, which could then be shipped to the Northeast. Thus, we do not project that the MSAT standards themselves will negatively impact gasoline produciton capacity under the renewable fuel mandate.

VII. Octane Balance

In this memorandum we summarize a number of changes to the gasoline pool by the various long term options. These changes can affect the octane level of the gasoline pool, however, it is important that the octane of gasoline be preserved as gasoline must continue to meet octane requirements. Changes in MTBE and ethanol use, the changes in iso-octane available from plants which were formerly producing MTBE, changes in butane content of gasoline and the reduction of benzene for meeting MSAT constraints, are all changes which will moderately or significantly affect the octane level of gasoline. In this supply analysis, we performed a simple octane analysis to gauge whether if the octane level of gasoline would be preserved if the long term options were implemented according to our analysis. Our octane analysis is limited to the various options under the Three-Fuel and Two-Fuel options.

This study examines the octane impacts of each of the long term options evaluated by this supply analysis. MTBE and ethanol volumes vary for each of the options. As MTBE varies, iso-octane content in gasoline varies inversely and at a rate of 70 percent of that of MTBE. To meet the RVP requirements of the RFG or CBG programs and to compensate for changes in MTBE and ethanol use, butane levels were adjusted accordingly. Next, the octane impacts reducing the benzene content of conventional gasoline to 0.70 volume percent benzene on average was analyzed to account for the octane impacts of new RFG. The analysis on cost included an additional element that RFG benzene levels be reduced further to accommodate blending without oxygenate to meet the MSAT requirements for the CBG options in lieu of RFG.This reduction would be accomplished by reducing the benzene of the FCC naphtha pool. As a first cut, this change was analyzed using the mix of benzene technologies used for the 0.7 volume percent average benzene case. We observed a large octane reduction due to the saturation of olefins in this stream. Then as a sensitivity we modeled this benzene reduction based on treating the benzene rich stream from the FCC unit with a Penex and isomerization unit to both saturate the olefins and isomerize the other compounds. The octane impacts of these two analyses are summarized in our analysis as a range of potential impacts on octane for this benzene reduction. Finally, this analysis also considered the impacts of a 0.95 volume percent benzene standard applicable to conventional gasoline. The blending octane levels of the various gasoline blendstocks used in this analysis are summarized in Table 7.

Table 7 Blending Octane of the Gasoline Blendstocks

	MTBE	Ethanol	Isooctane	Butane
Blending Octane (R+M)/2	110	115	100	94

The volume changes of MTBE, ethanol, isooctane, butane, and their impacts on pool octane as well as the octane impact of reducing benzene reduction are summarized in Tables 8 and 9.

Table 8 Octane Balance for the Three-Fuel Options

	Reference Case	RFG Oxygen Mandate			Renewable Fuel Mandate		
	% of National Gasoline Pool	% of National Gasoline Pool	Volume Change (%)	Impact on National Pool Octane	% of National Gasoline Pool	Volume Change (%)	Impact on National Pool Octane
Changes in Blending Components							
MTBE	1.5	1.5	-	0	0.8	-0.7	-0.15
Ethanol	1.8	1.9	+0.1	+0.027	2.4	+0.6	+0.16
Iso-octane	1.2	1.2	-	0	1.7	+0.5	+0.06
Butane	-	-	-0.02	-0.001		+0.44	-0.026
Impact of Benzene Reductions							
New RFG	0	3.2	-	-0.004	3.2		-0.004
CG (for CG Benzene Std)	-	55	-	-0.042	55		-0.042
Existing RFG	-	27	-	-	27		-0.10 to 0.045
Final Octane Number							
Without CG Benzene Std	88			88.01			87.94 to 88.09
With CG Benzene Std	88			87.97			87.90 to 88.05

Table 9 Octane Balance for the Two-Fuel Options

	Reference Case	RFG Oxygen Mandate			Renewable Fuel Mandate		
	% of National Gasoline Pool	% of National Gasoline Pool	Volume Change (%)	Impact on National Pool Octane	% of National Gasoline Pool	Volume Change (%)	Impact on National Pool Octane
Changes in Blending Components							
MTBE	1.5	1.8	+0.3	+0.066	0.8	-0.7	-0.15
Ethanol	1.8	2.2	+0.4	+0.108	2.4	+0.6	+0.16
Iso-octane	1.2	1.0	-0.2	-0.050	1.7	+0.5	+0.06
Butane	-	-	-0.3	-0.018		+0.27	-0.016
Impact of Benzene Reductions							
New RFG	0	16	-	-0.021	16		-0.021
CG (for CG Benzene Std)	-	42		-0.033	42		-0.033
Existing RFG	-	40	-	-	40		-0.16 to 0.067
Final Octane Number							
Without CG Benzene Std	88			88.09			87.87 to 88.10
With CG Benzene Std	88			88.05			87.84 to 88.07

These octane impacts should be considered to be approximately, due to the lack of detailed refinery modeling performed to date. However, they are indicative of the rough balance which occurs between the changes in blendstock use which are likely to occur under the various fuel control options.

VIII. Fuel Modifications Under the Various Cases

Reference Case - This is a year 2006 case. The finalized state MTBE bans and proposed state MTBE bans are assumed to be finalized and apply. The Tier gasoline sulfur standard is also presumed to be fully phased in.

3 Fuel Option with the RFG Oxygen Requirement in Place - the 7.8 RVP (Tulsa, OK, Southern Maine, Weber and Utah Counties, Utah, Pittsburgh, PA, Detroit, MI, Central and Eastern Texas, Clark and Floyd Counties, Indiana) the 7.2 RVP and the 7.0 RVP areas are converted to RFG.

The following example table shows a breakdown of the supply impacts of the 3-fuel option with the RFG oxygen mandate.

Table 10 Breakdown of Supply Impacts of the 3-Fuel Option

	7.0 RVP Area (3.1% of National Gasoline)		7.2 RVP Area (0.2% of National Gasoline)		Conventional Gasoline Pool
	MTBE Blended	Ethanol Blended	MTBE Blended	Ethanol Blended	
Fraction of the RVP Pool	0.7	0.3	0	1.0	
Initial RVP	6.85	6.85	-	7.05	
Oxygenate Addition (% of pool)	10	5.7	-	+5.7	
New RVP for blending with Oxygenate	6.73	5.75		5.75	
RVP Reduction	0.12	1.10		1.30	
Butane Reduction	- 0.18	- 1.65	-	-1.95	
Net Volume Change (% of pool)	+9.82	+4.05	-	+3.45	
Impact on National Hydrocarbon Supply (%)	-0.224	-0.015	0	-0.004	+0.22
Impact on National Ethanol Supply (%)	0	+0.05	0	+0.01	0
Impact on National MTBE Supply (%)	+0.22	0	0	0	-0.22
Overall Impact on National Supply (%)	-0.004	+0.035	0	+0.006	0

Impact on National Hydrocarbon Supply (%)	-0.02
Impact on National Ethanol Supply (%)	+0.06
Impact on National MTBE Supply (%)	0
Overall Impact on National Supply (%)	+0.04

3 Fuel Option Assuming that the RFG Oxygen Requirement is Rescinded and a 2.4 Percent of National Gasoline Volume Renewable Standard Applies - The 7,8 7.0 and 7.2 RVP areas are converted to RFG areas. The renewable requirement can be met in the Midwest through a refining industry trading program.

2 Fuel Study with the RFG Oxygen Requirement in Place - the 7.0 RVP area (Atlanta, GA; Birmingham, AL; Kansas City, KS and MO; and El Paso, TX) and 7.2 RVP area (East St. Louis, IL) are converted to RFG areas.

The following example table shows a breakdown of the supply impacts of the 2-fuel option with the RFG oxygen mandate.

Table 11 Detailed Breakdown of Supply Impacts of the 2-Fuel Option

	7.0 RVP Area (3.1% of National Gasoline)		7.2 RVP Area (0.2% of National Gasoline)		Conventional Gasoline Pool
	MTBE Blended	Ethanol Blended	MTBE Blended	Ethanol Blended	
Fraction of the RVP Pool	0.7	0.3	0	1.0	0.6
Initial RVP	6.85	6.85	-	7.05	7.6
Oxygenate Addition (% of pool)	10	5.7	-	+5.7	10
New RVP for blending with Oxygenate	6.73	5.75		5.75	6.73
RVP Reduction	0.12	1.10		1.30	-0.87
Butane Reduction	- 0.18	- 1.65	-	-1.95	-1.31
Net Volume Change (% of pool)	+9.82	+4.05	-	+3.45	+8.69
Impact on National Hydrocarbon Supply (%)	-0.224	-0.015	0	-0.004	-0.40
Impact on National Ethanol Supply (%)	0	+0.05	0	+0.01	
Impact on National MTBE Supply (%)	+0.22	0	0	0	+0.77
Overall Impact on National Supply (%)	-0.004	+0.035	0	+0.006	+0.37

Impact on National Hydrocarbon Supply (%)	-0.26
Impact on National Ethanol Supply (%)	+0.4
Impact on National MTBE Supply (%)	+0.3
Overall Impact on National Supply (%)	+0.39

2 Fuel Study Assuming that the RFG Oxygen Requirement is Rescinded and a 2.4 Percent of National Gasoline Volume Renewable Standard Applies - The 7.0 and 7.2 RVP areas are converted to RFG areas. The renewable requirement can be met in the Midwest through a refining industry trading program.

Federal CBG case Assuming that the RFG Oxygen Requirement is Rescinded and a 2.4

Percent of National Gasoline Volume Renewable Standard Applies- All gasoline outside of California is presumed to be Federal Clean Burning Gasoline (CBG).

California CBG case Assuming that the RFG Oxygen Requirement is Rescinded and a 2.4 Percent of National Gasoline Volume Renewable Standard Applies- All gasoline is presumed to be California Clean Burning Gasoline (CBG).

1. "Draft Economic Analysis of U.S. MTBE Productin Under an MTBE Ban," Pace Consultants, Inc.for EPA, May 2001.

2. Mathpro Inc., Costs of Meeting 40 ppm Sulfur Content Standard for Gasoline in PADDs 1-3, via Mobil and CDTech Desulfurization Processes, Study Performed for the American Petroleum Institute, February 26, 1999.